

Maritime Domain Awareness: Command, Control, Computers, Communications and Intelligence for the Thousand Ship Navy

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Abstract – The purpose of this paper is to present results of applying structured systems engineering methods, domain patterns, and tools to develop architectures, an information exchange standard, and a cost estimate of hosted mission applications for the Thousand Ship Navy Command, Control, Computers, Communications, and Intelligence system concept in support of the Global Maritime Partnership enterprise.

I. INTRODUCTION

Over millennia, the presence of naval forces with global reach correlates to peace and international prosperity. Encompassed by the Global Maritime Partnership (GMP) enterprise, Thousand Ship Navy (TSN) is a concept envisioned by Chief of Naval Operations (CNO) Admiral Mullen, USN in 2005 to provide overwhelming maritime power by forming coalitions of multinational security forces and navies. With no single national power currently positioned, economically or politically, to unilaterally provision a TSN, its capability includes voluntary participation of international signatories, nations' navies, commercial, and constabulary stakeholders.

In order to coordinate existing, albeit disparate systems, a top-level Command, Control, Communications, and Intelligence (C4I) architecture is identified to support the TSN operational architecture and missions. Through the application of structured systems engineering methods, domain patterns, and analysis tools, the study developed requirements, defined functions, and synthesized architecture alternatives.

A distinction is made in the study between GMP and TSN, in that GMP represents the international enterprise construct and TSN represents the force level needed to achieve the objectives of GMP. In the digital age, improvements in technology have reduced battlespace volumes so that fewer ships are required to dominate any ocean. Consequently, TSN capabilities can be achieved with fewer ship numbers as compared to the Athenian League, Pax Romana, and Pax Britannica eras. Regardless of the actual number of ships, TSN is an alliance of international partners who volunteer naval and constabulary assets that respond to transnational threats, delivery humanitarian aid, and respond to disasters and environment events.

A paradigm shift from the Global Fleet Station (GFS), the framework of TSN is based on an international rather than a U.S. framework. The TSN C4I system will need to be multi-tiered to achieve trust, confidentiality, and performance among participating stakeholders. These stakeholders operate; therefore TSN will operate, across legally defined jurisdictions of high seas, economic zones, and territorial waters.

II. PROBLEM DESCRIPTION

In 2006 Commandant of the Coast Guard, Admiral Collins, USCG, and CNO Admiral Clark, USN, put forward a maritime version of the North American Aerospace Defense Command concept. This concept renewed United States (U.S.) Coast Guard-Navy team commitment and highlighted the need for international maritime cooperation. At the root of this vision, new system capabilities are to supplement United States Navy (USN), United States Coast Guard (USCG), and international partner naval platforms to enhance global security. These concepts converged to support the GMP enterprise which the U.S. State Department adopted by implementing the Pacific Partnership and the Partnership of the Americas. In 2008, the U.S. National Security Council sanctioned GMP as an interagency strategy [1].

Global maritime security is a fundamental naval mission, i.e., protecting the Sea Lines of Communication (SLOC). The world's commercial fleet carries ninety percent of global exports and comprises approximately 46,000 commercial ships [2]. Dependent on secure SLOC, maritime commerce abhors explicit or implicit risks from criminal elements and political extremists. Protection of humanitarian aid ships and the use of global reach capabilities in distraught areas are examples of unconventional operations supporting the U.S. State Department 2007-2012 strategy, which aims to stabilize legitimate nations and thwart terrorism [3]. In this strategy the USN projects power to save lives and support humanitarian objectives. Recently, the international community has undertaken forceful humanitarian interventions that merge security and humanitarian efforts.

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For example, the relief efforts for the failed Somali state are requiring armed protection of humanitarian aid providers.

Today, the international maritime community employs disparate and independent systems for coordinating responses to transnational criminal threats, events requiring humanitarian assistance, and environmental disasters. For example, the Piracy Reporting Center [4] is a dispatch type system addressing only one of the three TSN missions. The objective of this study focuses on the underlying need of a common maritime C4I system of systems encompassing naval systems, constabulary systems, commercial systems, and other international partner systems.

III. The TSN Tenets

Principles guiding the operation of TSN are found in the International Outreach and Coordination Strategy for the U.S. National Strategy for Maritime Security, which is an extension of an earlier form of a U.S. Department of State policy. Notably, the strategy includes eight supporting plans to promote global economic stability and prevent hostile or illegal acts within the maritime domain. These plans include trade routes, communication links, and natural resources vital to the global economy. In awareness of the magnitude of effort needed to achieve global maritime security, the strategy emphasizes that a collaborative effort is required by agencies, nations, and private sector. Where the first of two strategic goals addresses coordinated policy, the second strategic goal addresses outreach [5]:

- Strategic Goal: Enhanced outreach to foreign governments, international and regional organizations, private sector partners, and the public abroad to solicit support for improved global maritime security.
- Strategic Objective #1: Build partnerships with other countries and the maritime community to identify and reach out to regional and international organizations in order to advance global maritime security.
- Strategic Objective #2: Coordinate U.S. and international technical assistance to promote effective maritime security in developing nations and critical regions.
- Strategic Objective #3: Coordinate a unified message on maritime security for public diplomacy.
- Strategic Objective #4: Provide U.S. missions abroad with guidance to enable them to build support for U.S. maritime security initiatives with host governments, key private-sector partners, and the general public abroad.

On the basis of these goals and objectives, the tenets of TSN are formed. TSN requires international cooperation in order to achieve global maritime security. Furthermore, this cooperation must be mutual where the participants are bound by the universal interest of security, stability, and economic prosperity. This mutual interest allows for partnerships to be formed voluntarily, with the intent of building trust and reciprocal actions of support. To foster

trust, TSN must employ a common and transparent method to react to transnational criminals, humanitarian need, and environmental disasters.

Mutual interest is envisioned to compel a new kind of global alliance for which tenets appear to be unprecedented. Both the U.S. Department of State and United States Marine Corps (USMC)/USN/USCG community strategies are oriented toward assuring economic prosperity of the global economy. From the U.S. point of view, 95 percent of trade is transported by sea. This comprised 20 percent of the Gross [Domestic] National Product (GNP) in 2000. Although parameters differ, other nation-states have sea trade components that are a significant percentage of their GNP. The study by Looney, Schrady and Porch D (2001) [6] on globalization illustrates how enhanced security of the maritime domain provides economic benefits for the global economy. Further, maritime security is essential to U.S. economic interests during the projected shift of economic dominance to the Association of Southeast Asian Nations (ASEAN), Japan, South Korea, Taiwan, Singapore, Hong Kong and China [7].

IV. Operational Domain Analysis

This operational domain analysis section describes TSN operational characteristics. Results of an Analysis of Alternatives (AoA) and Arena modeling provided TSN organizational insights, which are incorporated into the TSN concept of operations. Evolving from the concept of operations, an operational node structure along with allocated operational functions and needlines are described using operational scenarios. Mission success is postulated on the basis of operational processes developed from functional analysis. An Interpretative Structural Modeling (ISM) and Design Structure Matrix (DSM) analysis of the resultant operational architecture evaluates functional clustering and dependency patterns to improve functional coupling and functional cohesion. Both ISM and DSM resulted in favorable scores for the operational architecture.

A. Operational Functions

A dendritic model illustrates the cornerstone operational functions. Both Provide Intelligence and Perform Command and Control operational functions are needed to achieve the top operational function Provide TSN.

The Provide Intelligence operational function, shown in Fig. 1, is based on the intelligence pattern Task, Process, Post, Use (TPPU) to leverage its alignment with Network Centric Operations' (NCO) new communication service oriented paradigm [8]. An operational capability pattern, TPPU refines the C4I operational capability pattern with specific intelligence process flows and operational functions. The function provides periodic and non-periodic intelligence support to each member of the community of interest, where each member is both an information provider and consumer. By posting intelligence products the authorized users access the information for decision-

making; enabling their role in TSN. Intelligence is protected to the level of access granted using a three tier concept discussed in the concept of operations.

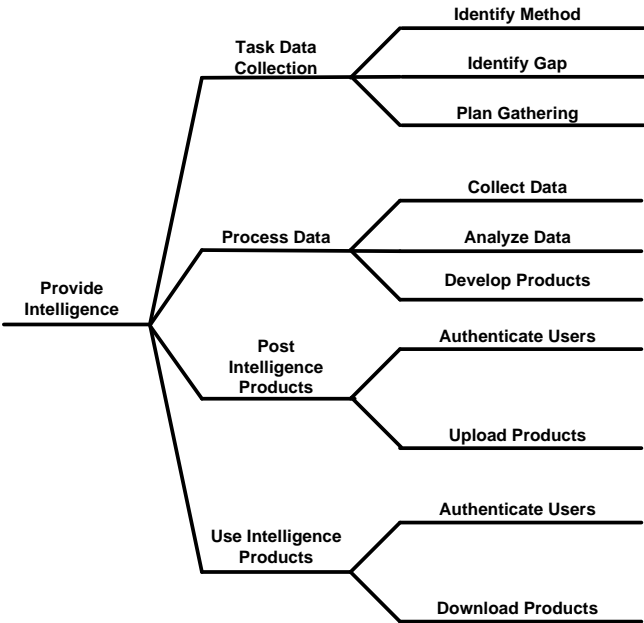


Fig. 1. Provide Intelligence Operational Function.

The Perform Command and Control operational function, shown Fig. 2, is based upon the Lawson model for Command and Control (C2) [9]. The operational capability pattern, Sense, Assess, Generate, Select, and Direct refines the C4I operational capability pattern with specific C2 process flows and operational functions. The environment and characteristics of objects of interest are sensed for changes in state from an objective state. An assessment transforms the information from Sense into transnational threat intentions and capabilities, humanitarian aid requirements, and disaster or environmental characteristics. Courses of action are generated to mitigate deviations from the objective state determined by international consensus. A preferred alternative course of action is selected with an evaluation of alternatives to assure conformance with international established criteria. The preferred alternative is planned in sufficient detail to direct TSN stakeholders with a coordinated set of tasks.

B. Committee Organization

The committee organizational model shown in Fig. 3, was found by the analysis described below to offer the best resource efficiency across the TSN missions. The other models considered were a team model and group model [10]. The team model is a hierarchical organizational structure with limited interaction among lower level stakeholders. The group model places all stakeholders at the same level and requires a high degree of communication among stakeholders. The committee model is a hybrid of the team and group models that has one “hub” stakeholder that manages “spoke” stakeholder interactions.

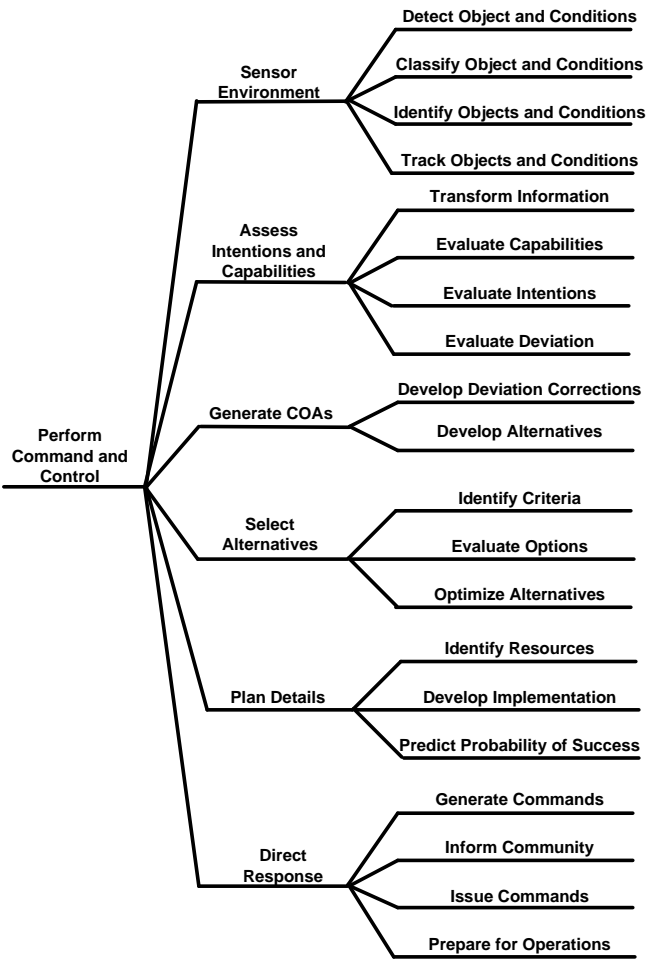


Fig. 2. Perform Command and Control Operational Function.

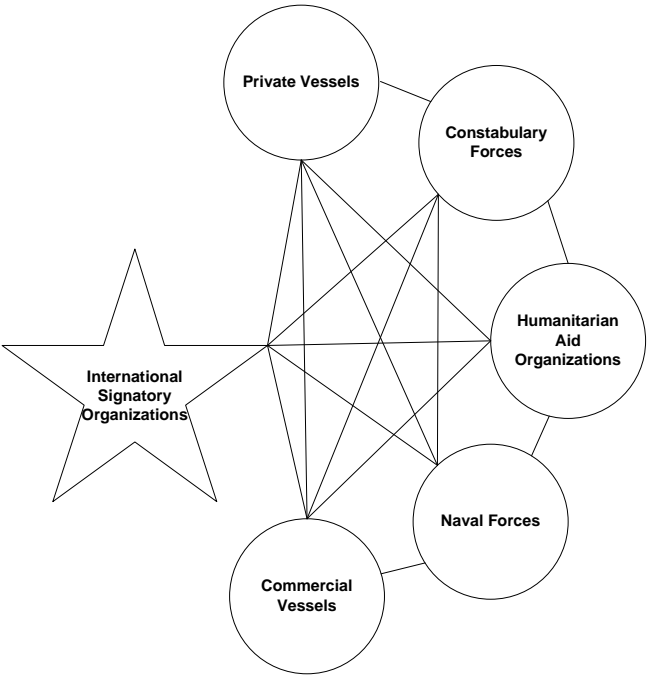


Fig. 3. Committee Organizational Model

By contrast to team and group alternatives, committee stakeholders employed more of their capabilities to accomplish the missions. This effect supports the TSN objective to promote widespread stakeholder involvement.

An AoA rating rubric was utilized to organize the qualitative and quantitative evaluation factors for each sub-alternative, all possible combinations of organizational alternatives and mission types. The organizational model with the highest aggregate score was identified as the preferred TSN organizational approach. Evaluation factors included: political feasibility, mission duration and resource usage (as determined from Arena modeling), number of relationships among stakeholders, number of new capability, and use of legacy capability.

The AoA employed a weighting distribution according to Table I and assigned equal weighting for the three missions: transnational threat enforcement, humanitarian aid, and disaster relief/protect environment response.

TABLE I

Analysis of Alternatives Weight Distribution

TSN Score Weighting	
Evaluation Factor	Weight
Political Feasibility	0.3
Arena Resource Duration	0.2
Arena Resource Usage	0.1
Number of Relationships	0.1
Number of New Capabilities	0.1
Use of Legacy	0.2
Sum	1

The largest weighting factor applied to the factors in Table I was assigned to political feasibility since it is a principal consideration of TSN. With each mission type having an equal weighting distribution, the committee model remained dominant. Within the range of weightings applied to mission importance during sensitivity analysis, the team model failed to achieve a score greater than either committee or group. To address the equally weighted missions, the committee model was selected as the preferred organizational model for TSN.

C. Arena Modeling Supporting Analysis

In support of the AoA organization analysis, Arena models were used to generate mission processing times and mission resource requirements for each sub-alternative. The operational functions from the dendritic results were grouped into three distinct Arena operational threads: direct mitigating response, situation awareness, and intelligence, as shown in Fig. 4, respectively. For each mission, the three operational threads were run concurrently, demanding stakeholder resources and calculated processing times that characterized the simulated organizational model.

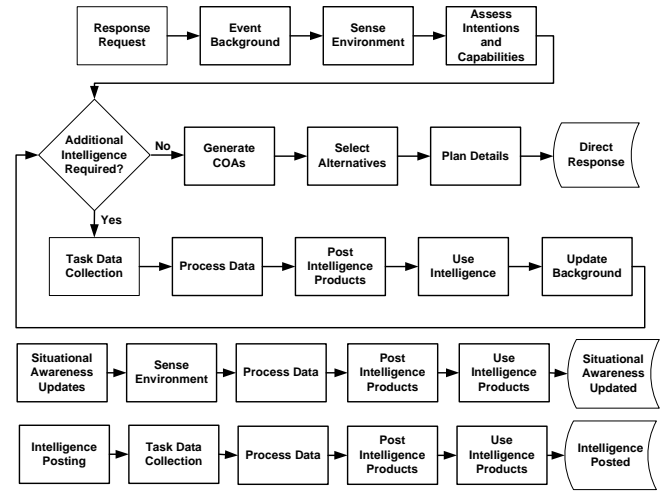


Fig. 4. Arena Model.

Each operational thread was stimulated by an occurrence event summarized in Table II. The transnational threat occurrence rate was derived from pirate attack rates in the Gulf of Aden from January to March 2009 [11]. The occurrence rate of disaster events was determined given there were 414 natural disasters requiring humanitarian aid in 2007 [12]. Environmental events were represented by the occurrence rate of oil spills exceeding seven metric tons over five years, 18.4 spills per year (2000-2004) [13]. The occurrence rate for humanitarian aid was the combination of 414 natural disasters and 34 armed conflicts in 2007 [12]. Each model assumed an exponential distribution parameter, λ , calculated from the reciprocal of average occurrence consistent with Equation (1). All events were assumed to be independent.

TABLE II

TSN Mission Average Event Arrival Time

Event	Mission Model	Average Arrival Time (hours)	Parameter Lambda
Transnational Threat	Transnational Threat Enforcement	60	0.0167
Disaster Relief	see below	106	0.0094
Protect Environment (oil spills)	see below	2380	0.0004
Combined Disaster Relief / Protect Environment	Disaster Relief / Protect Environment Response	101	0.0099
Humanitarian Aid	Humanitarian Aid	98	0.0102

$$f(x) = \lambda e^{-\lambda x} \quad (1)$$

D. TSN C4I Concept of Operations

The concept of operations for the TSN C4I, depicted in, is induced from the community organizational model, TSN mission types, and operational functions from the dendritic model. The TSN C4I gathers and fuses information, shown as white unidirectional arrows, from all participants within the operational area and promulgates the information across the TSN C4I system to participants based on their individual

access level. This allows the appropriate stakeholders, grouped by black lines, to perform mitigating actions, shown as green unidirectional arrows, in response to trigger events, depicted as transnational threats, humanitarian aid, and disaster relief/protect environment response. The overarching TSN C4I system network, shown as the cloud in the top left corner, has a combination of three distinct capabilities: TSN C4I backbone, shown as the red bidirectional arrow, TSN C4I participant edge, shown as the yellow bidirectional arrows, and TSN C4I broadcast, shown as the blue unidirectional arrows.

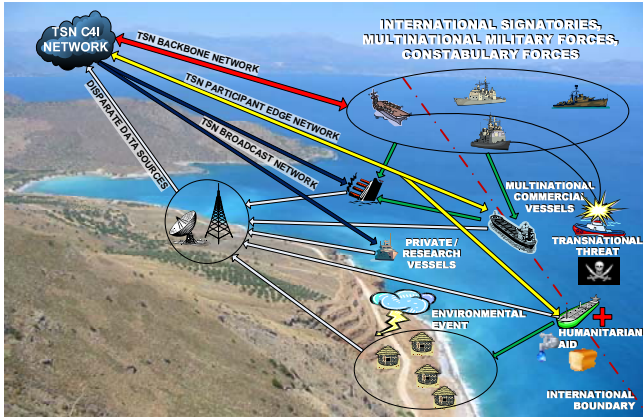


Fig. 5. TSN C4I Operational View

The TSN C4I backbone capability is the highest trusted level of the TSN C4I system and is reserved for international signatory organizations, naval forces, and constabulary forces. This capability is primarily tasked to push and pull information that is too sensitive to be passed indiscriminately, such as, but not limited to, the location and quantity of naval units, specific commercial shipping lanes, unsubstantiated sensor information, and other naval and constabulary intelligence. Furthermore, the TSN C4I backbone capability has unrestricted access to all information pushed from the lower levels of the overarching TSN C4I system.

The TSN C4I edge capability is reserved for the commercial shipping industry and humanitarian aid organizations. This system provides these stakeholders the ability to push trusted situation awareness information to the overarching TSN C4I system, while allowing limited pulling from the TSN C4I backbone capability. This limited pulling of information allows for sensor and other relevant intelligence information to be passed to these stakeholders without divulging the source of the information. The ability to access this intelligence information is critical for first responders to disaster relief/protect environment events and to mitigate transnational threats. Moreover, the TSN edge capability has unrestricted access to information pushed by the TSN C4I broadcast capability.

The lowest trusted level of the TSN C4I system, the TSN C4I broadcast capability, is reserved for connectivity among private vessels. These vessels push information to

the overarching system, such as Automated Information System (AIS) and Long Range Identification and Tracking (LRIT) information types, but are only able to pull a limited portion of TSN C4I information. This information is limited to local transnational threat alerts and the location of other private vessels in the operational area. However, the private stakeholder can be tasked to provide first response capabilities to disaster relief/protect environment events. If they accept, they are then given the ability to push additional situation awareness information, and pull from a limited version of the TSN C4I edge capability.

The TSN operational concept differs from Stabilization, Security, Transition, and Reconstruction, (STTR) operations as described by the Military Support to STTR Operations Joint Operating Concept (JOC). The central idea of SSTR operations is: "... U.S. policy carried out by U.S. military forces, civilian government agencies, and, in many cases multinational partners, will on helping a severely stressed government avoid failure or recover from a devastating natural disaster, or on assisting an emerging host nation government in building a 'new domestic order' following internal collapse or defeat in war" [14].

By contrast the TSN concept of operations carries out the consensus of the international community with naval and constabulary forces interacting with commercial and humanitarian aid organization stakeholders. The TSN concept includes similar missions stated in the JOC including delivery of humanitarian assistance, reconstruction of critical services, restoration of essential services, and establishment of rule of law [14]. These missions are implemented with leadership from supporting international organizations and support from volunteer forces and intelligence resources. The framework of the TSN C4I architecture, described in the remaining sections of this paper, differs from the JOC vision, the framework of which is centered upon U.S. military systems.

E. TSN Operational Nodes

Operational nodes are conceptual entities which include computers, communication resources and related capability. As shown in Fig 6, TSN is built from three principal operational nodes: command and control node, intelligence node and unit node. The latter node includes the following node instances: constabulary, humanitarian, commercial, private and navy. These nodes correlate to the principal stakeholders. Based on the committee model the international signatory stakeholder is assigned command and control, and intelligence nodes. The remaining stakeholders map one-for-one to their respective nodes. The nodes are involved to varying degrees in the conduct of operational scenarios as applied to completing a TSN mission.

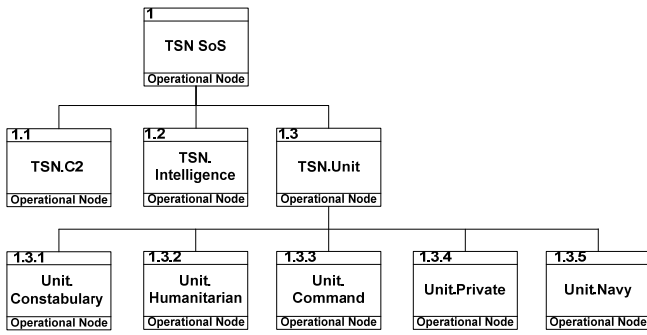


Fig. 6. Operational Node Hierarchy

F. TSN Operational Scenarios

The “evaluate range of options” operational scenario describes how TSN transforms international policy, objective state and Rules of Engagement (ROEs) into tactical constructs. An external international body, International Maritime Bureau (IMB) or International Maritime Organization (IMO), issues guidance to TSN concerning expectations and restrictions which are based on international community consensus building in reaction to historical and current events

The “collect and distribute intelligence” operational scenario describes how TSN performs intelligence collection, processing, and distribution. Sources of intelligence include the military, law enforcement, TSN stakeholders and open sources. The TSN continuously prepares intelligence products from TSN stakeholders and open sources while intelligence received from military and law enforcement is available on a restricted basis in response to an incident. This approach acknowledges the sensitivities of nation-states limits on access to their intelligence sources, without which they would not likely participate in TSN C4I.

The “situation awareness” operational scenario describes how TSN builds situation awareness for the TSN stakeholders. Sources of information include external sources from legacy regional maritime systems, such as, SHIPLOC, AIS, LRIT, and Piracy Reporting Center. Additional external sources include regional environment monitoring agencies and Global Maritime Distress Safety System. The intelligence node combines TSN unit node (i.e., navy, constabulary) sensed tracks with external information to generate operational pictures. For information management purposes, the operational picture has three versions consistent with the concept of operations.

The “transnational threat” operational scenario describes how military and law enforcement nodes conduct mutual enforcement operations. The intelligence node continues to process and post intelligence summaries and versions of the operational picture for authorized users. The command and control node develops alternatives from the enforcement mandate and then transforms them into tactical options. Candidate tactical actions are narrowed down to a definite course of action selected by predictive analysis supported by

historical patterns. The TSN unit node, i.e., navy and constabulary, while aware of the intelligence summaries and an operational picture responds to the directed course of action.

The “deliver humanitarian aid” operational scenario describes how humanitarian aid stakeholders or regional nation-state authorities coordinate with TSN forces to safely deliver aid. External entities request the safe delivery of aid to disadvantaged locations or disaster areas. The command and control node responds to the request by assessing any additional mission requirements from TSN operations. Given the range of possible methods for safe delivery of aid, TSN options are evaluated to determine the preferred course of action. A course of action is composed and communicated to the TSN unit node, i.e., navy, constabulary, humanitarian, commercial, and private.

Mission success analysis results are derived from Measures of Effectiveness (MOE) and Measures of Performance (MOP) for each operational scenario assuming a probability of success for each lowest level operational function of 0.9722. The operational scenario with the highest mission success is disaster relief/protect environment with 75 percent followed by humanitarian aid with 64 percent and last by the transnational threat enforcement with 63 percent. The arrangement of mission functions (serial or parallel) and their quantity are significant factors in determining the mission success. Further study of MOEs and MOPs are warranted using the tree analysis employed technique with subject matter expert judgments.

G. Operational Requirements

The following is a list of operational requirements derived by the study based on a combination of research and the results of operational function analysis.

- The TSN C4I system operational availability must be 0.99 (threshold).
- The TSN C4I system must support 24/7 continuous operations.
- The TSN C4I system should be suitable for vessels with Gross Weight Tonnage (GWT) > 300 tons (threshold), GWT > 1 ton (objective).
- The TSN C4I system must process maritime reports from multiple sources including AIS, LRIT, etc.
- The TSN C4I system must process intelligence information from combatant ships and intelligence agencies.
- The TSN C4I system must distribute situation awareness information to commercial vessels, private vessels, combatants, humanitarian aid vessels and constabulary vessels.
- The TSN C4I system must distribute situational awareness to the shipping industry, maritime organizations, non-government organizations (World Food Program, International Red Cross, etc.), ports and harbors, and enforcement agencies.

- The TSN C4I system must exchange information in multiple languages.
- The TSN C4I system must authenticate user roles to provide a trustworthy capability.
- The TSN C4I system must deny access to unauthorized users.
- The TSN C4I system should employ user interfaces, templates, and protocols that are internationally identifiable and available.
- The TSN C4I system hardware must scale effectively with respect to size, weight, and power with variability for use on large (GWT > 300 tons) or small vessels (GWT > 1 ton) (objective).
- The onboard TSN C4I system cost must be less than 2 percent of the vessel's original equipment configuration cost.

V. System Domain Analysis

Level one and level two system functions of TSN C4I are shown in the functional hierarchy, Fig. 7. They are arranged in an intuitive order from left to right culminating in full TSN C4I functionality. Provide C4I system function is modified from existing C4I functional capability patterns which describes implementation approaches to C4I operational requirements. An ISM and DSM analysis of the system architecture resulted in favorable scores.

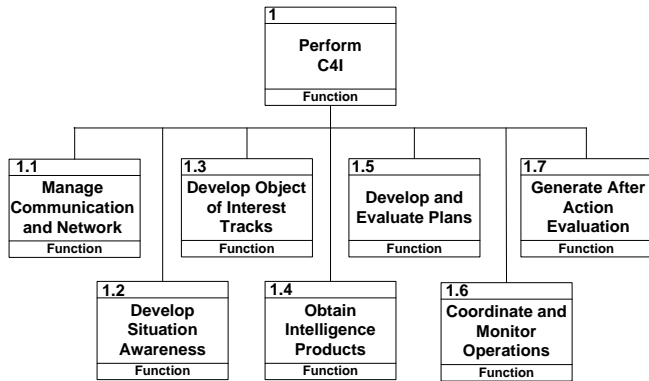


Fig. 7. System Function Top Level Hierarchy (recreated from COREsim®).

A. Operational to System Function Map

Operational functions are related to system functions, shown in Table III. Of particular interest, the Manage Communication and Network system function provides the means of stakeholder connectivity which impacts all other operational functions. The remaining system functions have distinctive mapping to the operational functions.

B. TSN C4I System Functions

Fig. 8, illustrates the top level arrangement the system functions in the form of an IDEF0 diagram. The identified input, output, controls and mechanism reflect the allocation

of system functions and foundation of the information exchange standard.

TABLE III
Operational View – 5 (OV-5)

System Functions	Operational Functions													
	Assess Intentions and Direct Response	Generate COAs	Plan Details	Select Alternatives	Sense Environment	Post Intelligence Products	Process Data	Task Data Collection	Use Intelligence Products	Alert Land Node	Alert TSN Node	Coordinate Unit Operations	Perform Unit Action	Process Unit Information
Manage Communications and Networking	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Develop Situation Awareness	X	X			X		X			X	X	X	X	X
Develop Object of Interest Tracks					X									X
Obtain Intelligence Products					X		X	X		X	X		X	X
Develop and Evaluate Plans	X	X	X	X	X							X		
Coordinate and Monitor Operations		X										X	X	
Generate After Action Evaluation		X												

The Manage Communication and Network system function provides inter-unit communications and networking, as well as intra-unit networking to enable operational and tactical collaboration. Communication management jointly manages communication links and networks with the use of a communications plan. The plan accommodates communication reach back to land sites. It also accommodates communication among vessels by Line of Sight (LOS) and non-LOS means. Considerations of the communication plan include: disparate communication systems; data forwarding; circuit bandwidth versus data type; spectrum management; transmission security issues; authentication methods and contingency circuits. Communications network establishes connectivity between Host Nation, Regional Nation, Non-DoD National agencies, International Organizations, International Non-Government Organizations, nations' navies, and constabulary forces.

Network operations provides continuity of operations over a range of conditions to include degraded network operations, disadvantaged network operations, limited communication bandwidth, and intermittent connectivity. The network routes information between the processing and storage components to support application services and common services. The network maintains status information regarding its nodes and interconnecting devices.

The Develop Situation Awareness system function provides inter-unit information from multiple sources including land based centers and TSN units. Situation awareness provides a graphical view of various overlays where each provides different views of information. A particular view of information may be restricted to certain

stakeholders. The following overlays are included: jurisdiction, tracks (commercial, nations' navies, constabulary, etc.), density of events, planned operations (armed, VBSS, reposition, etc.), boundaries and areas, navigation, topology, socio-political, cities and infrastructure, weather, and enforcement status/resources.

The Develop Object of Interest system function provides declaration and development of both human and non-human track files with multimedia information. Tracks are developed from organic and non-organic sensors and human intelligence. Tracks are either human or non-human objects, such as vessels. If provided, the error of a track is used or estimated to help distinguish closely-spaced tracks. Track information includes identification, priority (protected, monitored, suspicious, etc.), kinematic state, associated tracks, associated image, history, status, and assessment.

The Obtain Intelligence Products system function provides processed intelligence to select TSN units and land based centers. Multi-modal information sources are collected, analyzed, and correlated by TSN C4I to provide an integrated set of products for use by TSN stakeholders. Intelligence information is tagged with source, data type, date created, date accessed, keywords, abstract, size, and

access restrictions. Intelligence information includes text, images, audio, video, and biometric data, e.g., fingerprints.

The Develop and Evaluate Plans system function provides joint TSN developed plans to: respond to disaster and environment, deliver humanitarian aid, and provide transnational threat enforcement consistent with stated international policies.

Plans are jointly developed and coordinated including logistic requirements for Host Nation, Regional Nation, Non-DoD National agencies, International Organizations, International Non-Government Organizations, nations' navies, and constabulary forces. Collaborative evaluation of the plans looks for intended and unintended effects, non-lethal and lethal, of a plan in the context of the stated internationally recognized policy, and regional needs. Joint development assumes that a pre-existing navy combatant and constabulary force are in the area or a nation-state intends to provide assets. A plan identifies the situation context and location with evaluated enforcement options. Each option provides compliance to international policy an ROE, basis of intelligence, needed assets and their resources, timeframe whereby option remains valid, and probability of success.

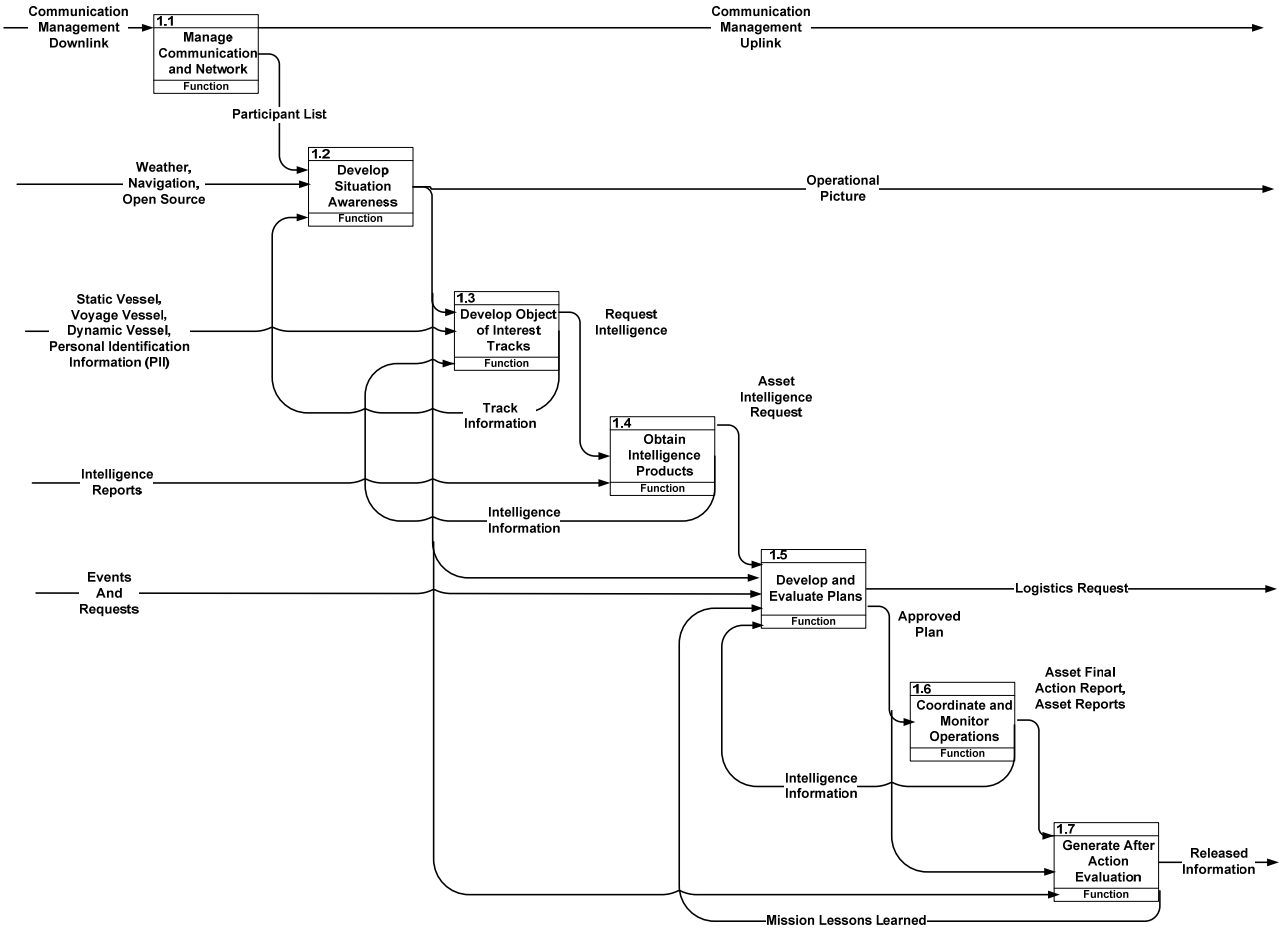


Fig. 8. A-1 TSN C4I System Context (recreated from COREsim®)

The plan is generated on the basis of an enforcement concern based on intelligence assessments or as a reaction to a particular event regardless of mission type. The plan identifies significant boundaries (territorial waters, economic zone, high seas etc.), areas (military, shipping, fishing, anchorage etc.), and navigation concerns. Boundary areas and navigation concerns are superimposed with the established enforcement jurisdictional zones. Each plan summarizes responsibilities, resource needs, communication plan and tactical restrictions.

The Coordinate and Monitor Operations system function provides tactical coordination among TSN force assets while executing assigned tasks. Primarily navies and constabulary force assets perform tasks of a COA. They receive and evaluate information, receive instructions, call for backup, call for fire, declare intentions of targets (whether hostile, friendly or unknown), coordinate vessel movements, specify handover responsibility, assess status of weapons, and perform inventory of goods and services.

The Generate After Action Evaluation system function provides generation, review, and release of news briefs, situation reports, and evidence material to TSN stakeholders. Following an operational action or training action, a report is generated which provides a summary of action and the effect of action. Processing of the asset reports is combined with force level planning and monitoring information to provide lessons learned for future missions, news briefs for public awareness, and information useful as evidence. Situation reports are generated prior to, during, and following any of the missions, such as transnational threat enforcement, humanitarian aid, and disaster and environment response.

C. Information Exchange Standard

An Information Exchange Standard was developed for the TSN C4I system. The style of the standard was formatted similarly to the resolutions ratified by the Maritime Security Council (MSC), a division of the IMB. Section 1 outlines the fundamental characteristics of the TSN C4I network and the scope of the standard. Section 1.2 defines the TSN C4I network, in a general sense, while Sections 1.3 and 1.4 scope the network.

Section 2 defines the types of information to be transmitted by all non-military, participating vessels within the TSN mission area. The four information categories listed are parallel to the categories defined in the AIS Performance Standard (MSC.74 (69) Annex 3, Section 6). Setting it apart from the AIS standard is the inclusion of LRIT information, identification of the ship's flag nation, the last transmission time to the TSN C4I network, and defining the safety related information transmitted.

Section 3 elaborates on the types of external inputs with which the TSN C4I network must interface. Section 4 defines the information refresh rates in a nation's territorial waters and international waters.

Section 5 defines the unique TSN information elements. The fifteen information elements are listed in Table IV.

TABLE IV

Information Exchange Standard Elements

Element	Nomenclature
TSN-001	Static Vessel Element
TSN-002	Dynamic Vessel Element
TSN-003	Event and Request Element
TSN-004	Planning Element
TSN-005	Asset Reporting Element
TSN-006	Open Source Element
TSN-007	Object Information Element
TSN-008	Intelligence Report Element
TSN-009	International Objectives Element
TSN-010	Common Operating Picture Element
TSN-011	Communications Link Element
TSN-012	Network Management Element
TSN-013	Tracking Element
TSN-014	Personal Identification Element
TSN-015	Logistics Request Element

The information elements in Table IV are derived from the COREsim® model and provide linkage between the stakeholders. Listed with each information element are the unique information segments that are required. These segments elaborate on the information types listed in Section 2 of the standard. Included with each information element are minimum durations to maintain tactical relevancy and informational truth within a constantly evolving mission area.

TABLE V

TSN Software Configuration Items

CSCI	Nomenclature
SW-001	Distributed Communications and Networking Management CSCI
SW-002	Distributed Situation Awareness Development CSCI
SW-003	Information Fusion CSCI
SW-004	Distributed Intelligence Product Acquisition CSCI
SW-005	Distributed Mission Analysis CSCI
SW-006	Distributed Mission Operations CSCI
SW-007	Distributed Mission Planning CSCI
SW-008	Asset Management CSCI
SW-009	Distributed After Action Report Generation CSCI

Section 6 defines both the Computer Software Configuration Item (CSCI) shown in Table V and the Hardware Configuration Items (HWCI) which are the External Communications HWCI and Networking HWCI.

D. Critical Technical Parameters

The TSN C4I Critical Technical Parameters (CTPs), shown in Table VI, are measureable critical system characteristics that, when achieved, allow TSN to achieve its operational capabilities. Response time and accuracy are consistent with legacy systems, for example, AIS and LRIT. Arguably, the

most important parameter, language translation enables understanding among the languages likely to be encountered by the multi-national TSN force. Reliability and continuity of operations CTPs concentrate on mission reliability.

TABLE VI

TSN C4I Critical Technical Parameters

Categories	Parameters	Values
Message Response	Situation Awareness Update	≤ 30 minutes
	Data Exchange Latency	≤ 5 minutes
Positional Accuracy	Spatial Mean Error	± 3 meters
Language Translation	Latency	< 10 seconds
	Accuracy	< one error per 100 words
	Language Types	English, French, Spanish, Japanese, Chinese, German
Reliability	MTBF	> 500 hours
	MTTR	< 1 hour
Continuity of Operations	Recovery Time Objective	< 8 hours
	Recovery Point Objective	< 8 hours

E. Cost Estimate

Several applications that apply constructive cost model equations are free or commercially available. Two were selected to generate estimates for TSN C4I. The Naval Postgraduate School's (NPS) web based COSYSMO application was the primary resource for systems engineering cost estimation. This application was provided by NPS Professor R. Madachy, PhD., who has expert insight into these cost models as he is a co-author of B. Boehm's, PhD., COCOMO II book [15] and a contributor to R. Valeridi's, PhD., COSYSMO book [16]. Costar™ 7.0 is a software cost estimation tool developed by Softstar Systems that allows for estimation of the early design phase. The application applies cost analysis equations based on the number of functional points which were determined from TSN analysis using the COREsim® model. An arbitrary computer language is assumed.

An estimated total for developing the critical mission applications to support the TSN C4I system implementing a committee organization results from the combination of both systems engineering and software engineering costs. With a confidence level of 50 percent for systems engineering estimate, Fig. 9, and 80 percent for software engineering estimate, Fig. 10, the total estimate cost is \$9.68 million assuming a \$60.00 labor rate.

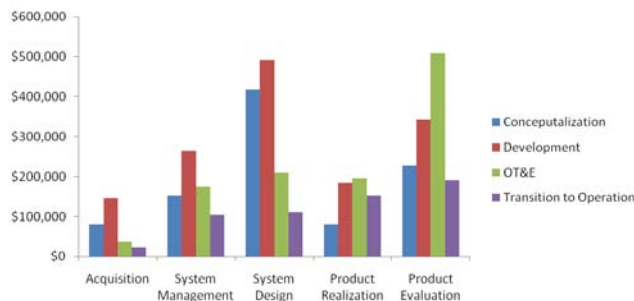


Fig. 9. TSN C4I Systems Engineering Cost Estimates per Phase.

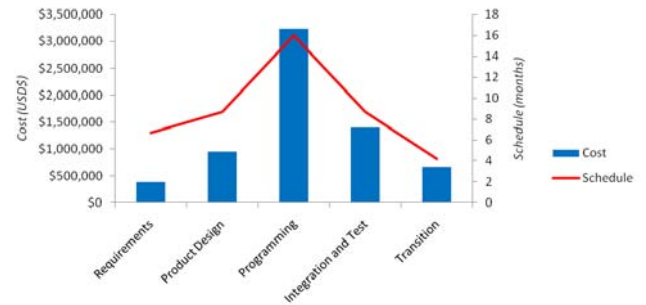


Fig. 10. TSN C4I Software Development Cost Estimates.

VI. Summary

The GMP enterprise objective is to pursue an international consensus to cooperatively provision a naval presence to stabilize global maritime operations, a concept associated to TSN. It requires a C4I segment to provide the ability to conduct the following missions: transnational threat enforcement, humanitarian aid, and disaster relief/protect environment response.

These missions are highly complex and cannot be carried out by only a single nation. At the USCG/USMC/USN flag officer level a vision has formed for Naval and Coast Guard maritime forces to combine resources. These forces would protect the SLOC from threats affecting international communities consistent with the restrictions of law. Complexities of enforcement actions on high seas, in economic zones and in territorial waters impact the TSN C4I development approaches.

This study concluded that a committee type organization model would be preferred for TSN C4I. Employing the committee organizational model, three C4I tiers would involve stakeholders by means of backbone, edge and broadcast capabilities. Backbone capabilities would include nations' navies, constabulary and intelligence units with the highest level access to TSN information and operations. Edge capability would include commercial and humanitarian organizations with access to the TSN information and isolated operations. Broadcast capabilities would include all other stakeholders, e.g., private stakeholders, with the lowest level access to the TSN situation awareness information.

TSN is organized to fulfill three crucial operational functions. In support of these functions, the TSN C4I system top level function was decomposed into seven system functions. Analysis identified essential data item flow to carry out these functions and the data items were formalized by drafting a TSN information exchange standard. Evaluation of the early concept architectures provided an estimated development cost of critical TSN C4I mission applications for systems engineering and software engineering.

It is not claimed that the results of this study presents a definitive TSN C4I solution that can be immediately funded

and implemented. However, this study has investigated the impact of important factors (policy to implementation) leading to the design of an effective system, some of which have not been noted in earlier TSN studies. It is hoped that the study can serve as a basis for follow-on systems engineering efforts.

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